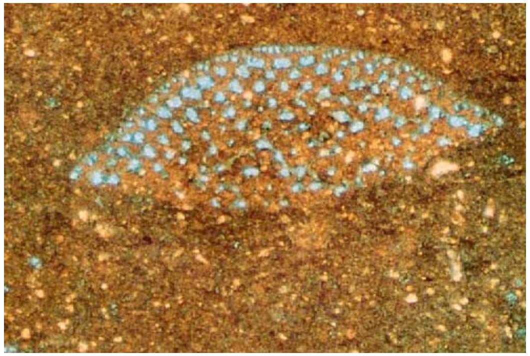
Carbonate Petrophysics



30 pu Limestone
Courtesy of F. Jerry Lucia

Rudhist: Middle East Well
Evaluation Review# 15, 1994

High Permeability Grainstone:
Petrophysical and Geomechanical
Issues in Carbonate Oilfields.
Austin Boyd, Schlumberger

R. E. (Gene) Ballay, PhD

Carbonate Petrophysics

Manual Content

COURSE OVERVIEW

This five-day course is for Engineers, Geologists and Team Leaders who require ***an understanding of the complexities of open-hole carbonate log analysis***. Participants will learn to ***characterize rock quality visually*** (thin sections, CT-scan, etc) ***and numerically*** (routine core analyses, capillary pressure, etc) and to then ***relate*** those results ***to both routine and specialty open-hole log responses***. The ***complementary nature of the various tools and techniques*** are discussed and ***illustrated with actual carbonate data.***

- Continued Following Page -

Carbonate Petrophysics

Manual Content

ABOUT THE COURSE
Carbonate petrophysics begins with a ***contrast of carbonates and sandstones***, followed by ***reservoir classification*** according to the Lucia Petrophysical Classification methodology. Thin sections and CT-Scans are used for ***visualization*** while capillary pressure serves to ***quantify the differing properties***.

- Continued From Preceding Page -

Individual ***logging tools*** (both ***routine and specialty***) are introduced; ***carbonate responses*** are ***illustrated with actual data***. Archie's exponents are discussed within the context of both his original data sets, and carbonate specific measurements. The ***complementary attributes of each tool and technique*** are used to identify and evaluate complex carbonate reservoirs, as illustrated with actual applications.

Carbonate Petrophysics

Manual Organization

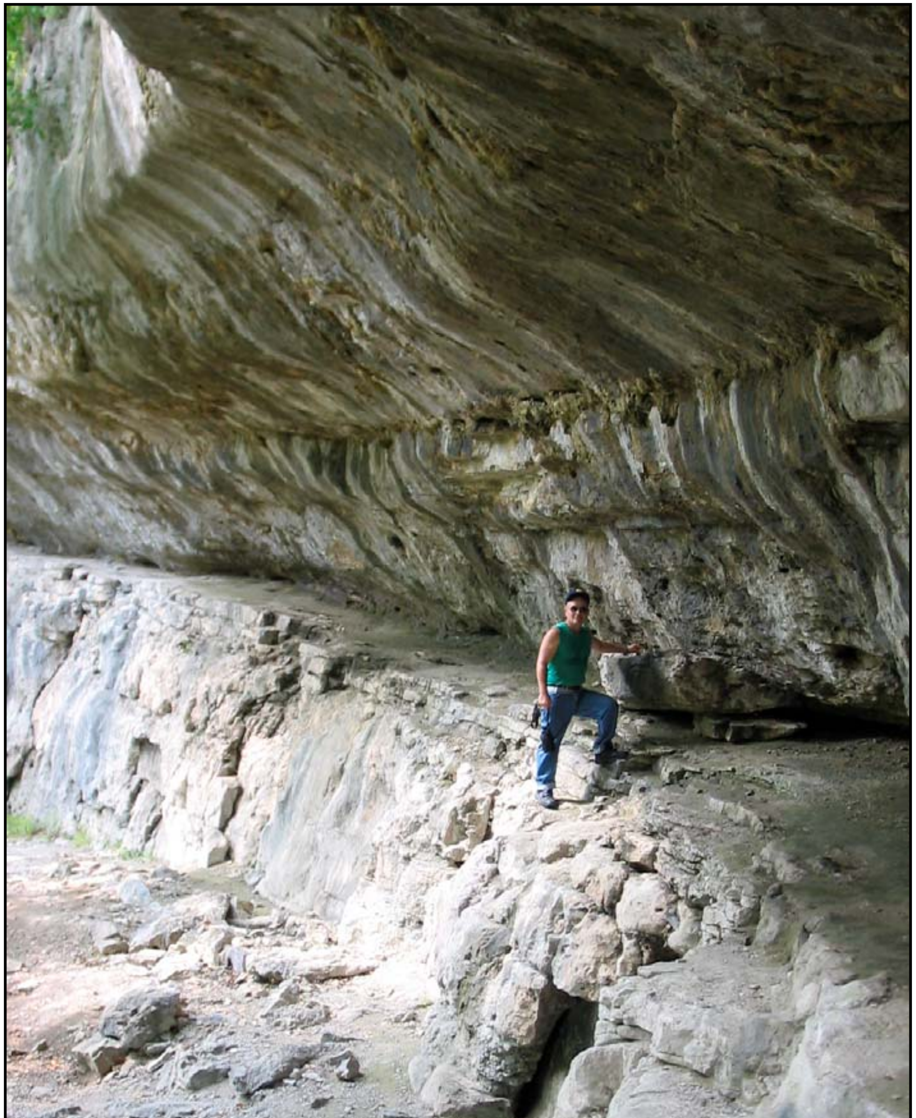
YOU WILL LEARN HOW TO

- ***Recognize the key distinctions*** between carbonates and sandstones, and understand the implications of those differences upon modern logging tool responses and formation evaluation methods
- Perform both ***quick-look and detailed interpretations***, taking into account carbonate complexities
- Design a ***cross-discipline formation evaluation program*** that will characterize the interpretational parameters associated with a specific reservoir, and facilitate complete analyses

- Continued Following Page -

Carbonate Petrophysics

Manual Organization



The Devil's Promenade, SW Missouri

- Continued From Preceding Page -

Carbonate Petrophysics

Typical Five Day Presentation - Customized Agenda Upon Request

Day 1

Start	Stop	Duration	Topic
830	915	45	Course Introduction
915	930	15	Carbonate vs Sandstone
930	945	15	Break
945	1000	15	Thin Sections
1000	1045	45	Lucia Petrophysical Classification
1045	1100	15	Break
1100	1200	60	Lucia Classification
1200	1300	60	Lunch
1300	1400	60	Capillary Pressure
1400	1415	15	Break
1415	1500	45	Rock Quality and Cutoffs
1500	1515	15	Break
1515	1545	30	CT Scan with Carb Examples
1545	1615	30	GR in Carbonate
1615	1630	15	Review and Feedback

Day 2

Start	Stop	Duration	Topic
830	945	75	Sonic in Carbonate
945	1000	15	Break
1000	1100	60	Rhob / Pef, WL & LWD in Carbonate
1100	1115	15	Break
1115	1200	45	Rhob / Pef, WL & LWD in Carbonate
1200	1300	60	Lunch
1300	1415	75	Neutron, WL & LWD in Carbonate
1415	1430	15	Break
1430	1545	75	Specialty Sonic in Carbonate
1545	1600	15	Break
1600	1615	15	Porosity Log QC / Carb Exmples
1615	1630	15	Review and Feedback

Carbonate Petrophysics

Typical Five Day Presentation - Customized Agenda Upon Request

Day 3

Start	Stop	Duration	Topic
830	900	30	Phi / Mineralogy from Core
900	930	30	XRD/XRF/etc Mineralogy
930	945	15	Break
945	1030	45	Resistivity Tools & Constraints
1030	1045	15	Archie's 'm' Exponent
1045	1100	15	Break
1100	1200	60	Archie's 'm' Exponent
1200	1300	60	Lunch
1300	1400	60	Cabin Creek Field-Williston Basin
1400	1415	15	Break
1415	1530	75	Archie's 'n' Exponent
1530	1545	15	Break
1545	1600	15	QL Techniques
1600	1615	15	Arabian QL Evaluation
1615	1630	15	Review and Feedback

Day 4

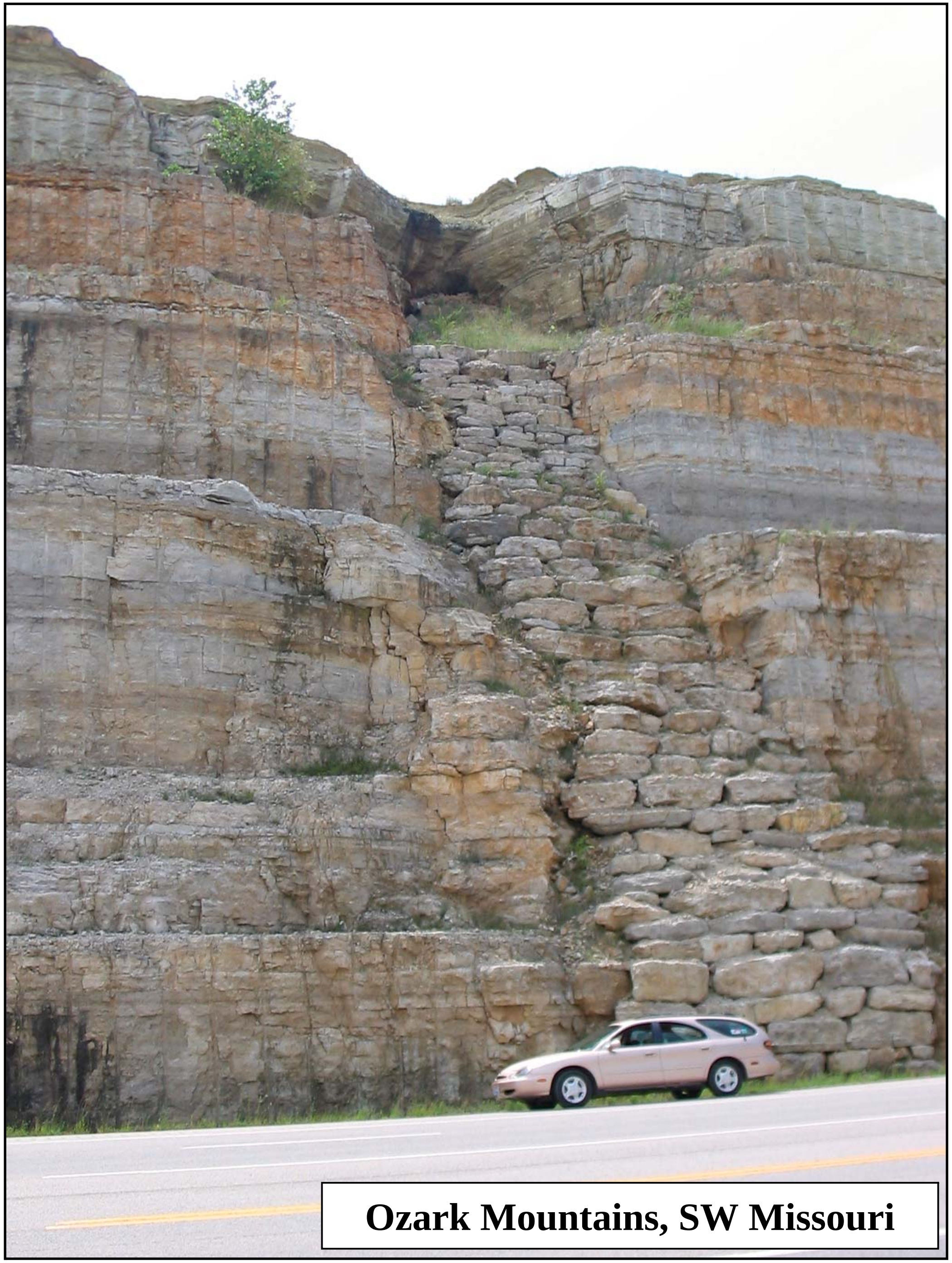
Start	Stop	Duration	Topic
830	945	75	Pickett Plot
945	1000	15	Break
1000	1100	60	Pulsed Neutron Log
1100	1115	15	Break
1115	1200	45	Pulsed Neutron Log
1200	1300	60	Lunch
1300	1345	45	PNL Log-inject-log
1345	1400	15	Break
1400	1500	60	BH Gravity Meter
1500	1515	15	Break
1515	1600	45	Pressure Profiles
1600	1615	15	Linear Correlation
1615	1630	15	Review and Feedback

Carbonate Petrophysics

Typical Five Day Presentation - Customized Agenda Upon Request

Day 5

Start	Stop	Duration	Topic
830	945	75	Image Log
945	1000	15	Break
1000	1115	75	Dielectric Log
1115	1130	15	Break
1130	1200	30	Basic NMR
1200	1300	60	Lunch
1300	1415	75	Basic NMR
1415	1430	15	Break
1430	1545	75	Carbonate NMR
1545	1600	15	Break
1600	1615	15	Course Summary
1615	1630	15	Review and Feedback



Ozark Mountains, SW Missouri

The Gasconade, Gunter, and Eminence are exposed at the Natural Bridge. The Gasconade dolomite is the uppermost layer, the Gunter sandstone is in the middle, and the Eminence dolomite is the lowest layer. Ha Ha Tonka, SW Missouri

- **Sandstone** - ***Diagenesis*** typically limited to ***compaction and cementation***
- **Carbonate** - ***Diagenesis*** includes ***cementation, compaction, dolomitization, and dissolution***

The Natural Bridge (from distance, see the light in the background) and then up close, looking 'under the bridge' into the sink hole beyond

Carbonate Petrophysics

- Recognition (alphabetical) of material used in the Course
  - ***My apologies if I've omitted anyone - Please bring it to my attention***
  - Additional material being reviewed and will be credited as it is incorporated

- Aguilera, Roberto - Servipetrol
- Allen, David - Schlumberger
- Baker WWW
- Balliet, Ron - Halliburton
- Black, Andy - Edcon Gravity and Magnetics
- Blum, Michael - Baker Atlas
- Bona, Nicola - AGIP
- Chen, Songhua, Baker Atlas
- Chitale, Vivek - Halliburton
- Clerke, Ed - Saudi Aramco
- Cox, Roy - Consultant
- Crain, Ross - Consultant

- Dennis, Bob - Schlumberger
- DeSouza, Hugh - SGS Lakefield Research
- Diederix, Michael - Shell
- Doveton, John - Kansas Geological Survey
- Edwards, Carl, Baker Atlas
- Eberli, Gregor - University of Miami
- Ehrenberg, Steve - Statoil
- Flaum, Charles - Schlumberger
- Funk, Jim - Aramco
- Gelinsky, Stephan - Shell
- Guy, Bill - Kansas Geological Survey
- Halliburton WWW
- Harlo, Carlos - Occidental
- Hartmann, Dan - Consultant
- Heil, Dick - Retired Aramco
- Hess, Lillian - Long Island University

- Kessler, Calvin - Halliburton
- Jones, Pete - Saudi Aramco
- Lacazette, Alfred - NaturalFractures.Com
- Lynn, Jack - Aramco
- Lawrence, Tony - Consultant
- Lucia, Jerry - Bureau of Economic Geology
- McLean, Rick - Consultant
- Moinard, Laurent - Consulant
- Parra, Jorge - Southwest Research Institute
- Polkowski, George - Aramco
- Quinn, Terry - Baker Atlas
- Ramakrishnan, T. S. - Schlumberger
- Rasmus, John - Schlumberger
- Sanders, Lee - Halliburton
- Schlumberger WWW
- Siddiqui, Shameem - Saudi Aramco

- Smart, Chris - British Petroleum
- Strauss, Jonathan - Consultant
- Stromberg, Simon - Reservoir Management Ltd (UK)
- Torres-Verdin, Carlos - University of Texas
- Toumelin, Emmanuel - University of Texas
- Westphal, Hildegard - Erlangen University, Germany
- Zhang, Gigi - Baker Atlas

Carbonate Petrophysics FAQs

•My ***First, and Top Priority***, is to ensure a-priori that the Course meets the Client's expectation. I suggest that one B&W copy of the Manual (two Power Point slides per page, printed front and back for a total of ~ 3000 / 4 = 750 paper pages) be produced and posted to the Client for review. Reproduction will be about $US75, mileage to / from the Print Shop about $US50 and postage additional (dependant upon the actual destination).
•The focus of the Course is on carbonate matrix issues, and not fractured reservoirs. Course Content issues for Client Consideration are summarized below – *please read these and consider them carefully.*
•If the Client determines they want to proceed with the Course, this expense will be deducted from the Registration Fee. If the Client determines the Course is not what they are looking for, they owe for only the above manual production / shipping expenses (these expenses to be reimbursed within 30 days via either electronic payment in $US or a $US check drawn on a USA bank).

Course Content Issues for Client Consideration

Please read and consider carefully.

•Modules for the basic techniques typically begin with an introduction to the physics behind the actual measurements. This is a conscious and deliberate decision, based upon my experience as both a practicing petrophysicist and as a teacher. Many times I have discovered that even those with several years of experience, are not aware of some of the basic physical principles, and have thus compromised their use of the measurements.
•I realize, however, that there are audiences which are not interested in the Basic Physics and possibly not even in an Introduction to Basic Tools / Techniques. Please review the default set-up to ensure it satisfies your objectives.
•*Continued following exhibit*

Course Content Issues for Client Consideration

Continued

•The Introduction Module contains a slide count and suggested schedule, with specified amounts of time allotted to specific topics. In some cases, there is a condensation of slides in going from the manual (slide count) to the actual course: not all slides in the manual are presented in the course: linear correlation is one example.

•Not all modules (Field Studies, for example) in the hardcopy are covered in the presentation, but rather are present for future review and reference, when the basic tools and techniques have been developed in class.

•There may be audiences which are 'application oriented'. Please review the default set-up to ensure it satisfies your objectives.

•Most of the modules have an Application Example included, which can be 'worked in class', or 'reviewed in class' or 'left for the attendee to review in their leisure'. I have found that some folks like to have problems to work, and others don't care for them (and in fact disapprove of spending course time in this manner), and I typically ask this very question in the Introduction Phase. It's preferable, however, to know the preference in advance. I would suggest that the included application examples be reviewed with an eye towards

- •Are they the 'kind of problems' that you are looking for in the course?
- •Shall they be 'reviewed' or 'worked' in class, or left for attendees to 'review at their leisure'.

•Please note that allowing time for problem solving will mean less time for technique presentation, as the time allocated in the course schedule will be adhered to in either situation.

•My ***First, and Top Priority***, is to ensure a-priori that the Course meets the Client's expectation. ***Please work with me, in advance of scheduling the course, to ensure that every requirement has been considered.***

R. E. (Gene) Ballay's 29 years in petrophysics include research and operations assignments in Houston (Shell Research), Texas; Anchorage (ARCO), Alaska; Dallas (Arco Research), Texas; Jakarta (Huffco), Indonesia; Bakersfield (ARCO), California; and Dhahran, Saudi Arabia. His carbonate experience ranges from individual Niagaran reefs in Michigan to the Lisburne in Alaska to Ghawar, Saudi Arabia (the largest oilfield in the world).

He holds a PhD in Theoretical Physics with double minors in Electrical Engineering & Mathematics, has taught physics in two universities, mentored Nationals in Indonesia and Saudi Arabia, published numerous technical articles and been designated co-inventor on both American and European patents.

At retirement from the Saudi Arabian Oil Company he was the senior technical petrophysicist in the Reservoir Description Division and had represented petrophysics in three multi-discipline teams bringing on-line three (one clastic, two carbonate) multi-billion barrel increments. Subsequent to retirement from Saudi Aramco he established Robert E Ballay LLC, which provides physics - petrophysics consulting services.

He served in the U.S. Army as a Microwave Repairman and in the U.S. Navy as an Electronics Technician, and he is a USPA Parachutist and a PADI Dive Master.